Stanislaus River Salmonid Habitat Use Investigation Technical Proposal

Executive Summary

The Fisheries Foundation, Wildlands, and the Institute for Natural Systems Engineering will team to implement the Stanislaus River Salmonid Habitat Use Investigation. The purpose of the study will be to determine fish and fish habitat response to different operational flows from Goodwin Dam into the lower Stanislaus River. The objectives of this proposal are to conduct a preliminary investigation to test survey methods, validate the data analysis approach, and define how best to expand the effort to the entire Stanislaus River between Goodwin Dam and the confluence with the San Joaquin River.

The team's will test two state-of-the-art approaches to determine the effects of various flow levels on fish use and habitat quality of the lower river. One approach employs an empirical statistical sampling survey design to measure habitat response under different flows. The second involves developing habitat models based on stream geomorphology and 2D hydraulic models under a range of streamflows to predict fish and fish habitat response versus streamflow regimes. Both methods will depend on intensive surveys of fish and river habitats. The common habitat unit will be 2-D surface polygons (at a specific flow) representing mesohabitat units of distinct habitat features on the scale of approximately 1000 square feet per unit. Fish densities in habitat units will be determined through two surveys of 5 half mile long reaches of the river. The sample reaches will be chosen from the estimated available total of 115 reaches in the lower 57.5 miles of the Stanislaus River below Goodwin Dam. The two surveys will encompass two different and normal flow ranges. Fish sampling will be conducted by snorkel surveys except in the lower reaches where visibility may be too low, in which case electrofishing or another viable alternative method is planned. Physical sampling will be conducted concurrently and will include standard parameters such as water temperatures, depth, velocity, substrate, cover and proximity to cover, bank slope, and distance from mouth. Fish densities by species and life stage and physical habitat parameter data for sampled polygons by survey and by reach will be input into GIS databases that can be employed to provide ArcMap tables and figures for data analysis and reports. Habitat and fish response measured at the sampled flows will be will be depicted empirically. Habitat and fish response over the two flows will developed using 2-D hydrodynamics and habitat models that incorporate the same physical parameters measured in the empirical data set. 2D hydrodynamics and habitat will be generated in five reaches of river for the two survey periods. Most of these sites will overlap empirical data collection sites. Modeling and mapping will be done such that results can be extrapolated to the entire river. The project team is made up of experienced field biologists, a statistician, hydraulic engineers, and project managers capable of planning and implementing the proposed project.

Technical Approach

The Fishery Foundation of California (FFC), Wildlands Inc. (Wildlands) and the Institute for Natural Systems Engineering of Utah State University (INSE) will join together to accomplish the Statement of Work. The team will employ and integrate two state-of-the-art approaches in defining fish habitat use and quality of lower Stanislaus River habitat under different flow regimes. One approach will be an empirical survey sampling and parametric statistical analysis approach (Cannon and Kennedy 2004) and the other using 2D hydrodynamic and behavioural rule–based habitat modeling (Hardy and Addley 2003). Both approaches incorporate the use of state-of-the-art GIS technologies and integrate the analysis and information obtained in biological and physical surveys of the LSR. The primary survey method will be snorkel surveys, wherein the FFC will expand upon its snorkel surveys from 2000 to 2005 to map physical habitat and fish habitat use in the LSR. These surveys provide information on seasonal use, abundance, and distribution of species and life stage within species of fish using the LSR (Cannon and Kennedy 2002). This survey will be conducted again in 2005-2006 concurrent with the proposed study. The proposed study will expand upon this information to map habitat and habitat use at two flow regimes from Goodwin Dam to the San Joaquin River.

The empirical approach will be similar to studies the FFC team has been conducting on the lower American River over the past several years wherein habitat is mapped on a mesohabitat[1] scale and snorkel surveys are conducted within habitat polygons for the purpose of determining fish response to meso-habitat type. The major difference will involve mapping the entire habitat in five reaches in the LSR under two different flow regimes to quantify habitat quality and quantity, and then sampling among meso-habitat types to statistically estimate overall fish abundance and use patterns and habitat quality at different managed flows. The basic approach will be an empirical statistical based approach based on survey sampling and traditional parametric statistical analyses. This approach provides a spatially extensive view of fish habitat in the river at two different flows.

The spatially extensive empirical approach can be integrated with and extended over a wide range of flows using a state-of-the-art 2D hydrodynmics and habitat modeling approach that has evolved from the traditional Instream Flow Incremental Methodology (IFIM). The 2D hydrodynamics and habitat modeling approach allows both micro and meso-scale habitat assessment based on depth, velocity, substrate, proximity (distance) to cover and/or any other mappable habitat feature. The snorkel survey data will be designed for use in flow-habitat relationships similar to the microhabitat models developed within the Physical Habitat Simulation (PHABSIM) component of the IFIM (Bovee 1982), but will include meso-scale habitat features. These are features found in the immediate surroundings of the fish that are fairly distinct (observable and measurable) stream unit with uniform flow, substrate, and water surface slope, bed topography, cover, bank conditions, riparian vegetation, and depth. Instead of sampling individual fish focal points as commonly done in traditional PHABSIM/IFIM, the proposed approach is based on sampling meso-scale habitat units and determining how many fish are observed in the units and what the specific habitat conditions are in these units. Statistics on use (density) by meso-scale habitat type can be related to the amount of habitat types by flow. Rubin et al. (1991) and Thomas and Bovee (1993) suggested

[1] Mesohabitat is a scale between the microhabitat at the focal point of an individual fish and reach or watershed macrohabitat scales such as riffle, pools, and runs.

the alternative of using 2-D surface-area cells for developing habitat suitability criteria instead of the standard IFIM PHABSIM procedure. **<u>By basing habitat suitability curves on cell data, no adjustment is needed for habitat availability if all habitat cells are mapped and sampling is stratified among habitat types</u>**. It is these approaches (described in more detail by Hardy and Addley 2003) we propose to use on the LSR for the habitat modeling portions of the study with the support of the INSE. This approach has been used successfully on numerous rivers such as the Klamath River, McKenzie River, Pit River, Oak Grove Fork Clackamas and is currently being used on the Trinity River.

Sampling habitat units and relating use patterns to environmental conditions that relate to flow in the units will provide information needed on the capacity of the LSR to rear young salmonids over a range of flow conditions. John Williams in a Fish Bulletin Paper stated: "*More observations of habitat use like those of Jackson (1992) would be helpful, especially if they are directed toward developing a better understanding of the way juvenile Chinook use habitat rather than 'habitat suitability criteria' for PHABSIM studies*" (Williams 2000).

Though the snorkeling procedure employed by FFC in the 2000-2005 surveys is standard, its application in an array of two-dimensional cells or polygon habitat units, each with narrow if not unique habitat conditions that are representative of habitats throughout the river is a relatively new approach being used in instream flow assessments. In this approach fish use is related to habitat conditions in the units and habitat conditions in the units are related to flow, then streamflow is related to the value or quantity of habitat or the production capacity of the river (e.g., LSR). If habitat use can be translated into habitat value, then habitat use patterns can help define habitat restoration needs and alternatives. Williams (1999) related that defining habitat for such purposes has not been satisfactorily resolved, especially in large rivers such as the LSR. The project objective is to create geo-referenced maps that describe habitat use of juvenile Chinook salmon and rainbow/steelhead trout at two or more discrete flows on the LSR between Goodwin Dam and the confluence with the San Joaquin River. Habitat use will be described quantitatively in terms of distribution and density of salmonids relative to physical habitat attributes for each studied flow. The results from two reaches will then be extrapolated to a wide range of flows using 2D hydrodynamics models so that the utility of this approach can be determined for future studies.

The FFC team includes Trevor Kennedy (FFC) who will lead the field surveys efforts, Tom Cannon (FFC/Wildlands) who will lead the database and statistical analyses efforts, and Craig Addley (INSE) who will lead the 2D hydrodynamics and habitat modeling effort. The following sections provide a summary description of these efforts.

Preliminary Field Surveys

FFC will conduct a year of preliminary fish and fish habitat surveys of the LSR as defined in the final study plan. The preliminary surveys will be a prelude to more comprehensive surveys in subsequent years. The preliminary surveys will focus on subsections of the river to determine potential technical and logistical problems that may inhibit subsequent defining surveys. Five ½-mile reaches will be surveyed for fish and fish habitat, and two of these will have a 2-D habitat model developed.

Locations: Five reaches of the LSR will be surveyed for fish and habitat as representative of the habitat types of the entire LSR. Locations tentatively chose are Goodwin, Lovers Leap, Orange Blossom Bridge, Oakdale and Caswell (Figure 1). These locations were chosen as they represent locations that have been surveyed by FFC and others with ready access.

Fisheries Surveys

FFC will conduct fish surveys in the LSR as follows:

Sampling Method: The survey methodologies will include snorkel surveys where visibility allows and electrofishing[2] where visibility does not allow snorkeling. Based on experience, snorkeling becomes difficult in the lower river downstream of Oakdale, therefore we believe it may be necessary to use back-pack and/or boat electrofishing gear if the lower river is to be covered. Seines would not be effective as much of the habitat is deep or heavy with debris. Polygons in center-river at Oakdale and Caswell sites will use average catch statistics for screw trap data when possible. Daily catch will be converted to 2-D area of polygons by converting screw trap data to per unit area from velocity/volume measurements.

[2] Use of electrofishing gear may be problematic if permission cannot be obtained from DFG or NMFS. Permits for proposed sampling will be submitted immediately after date of award. It may also be possible to use other available permits already existing among agencies or contractors.

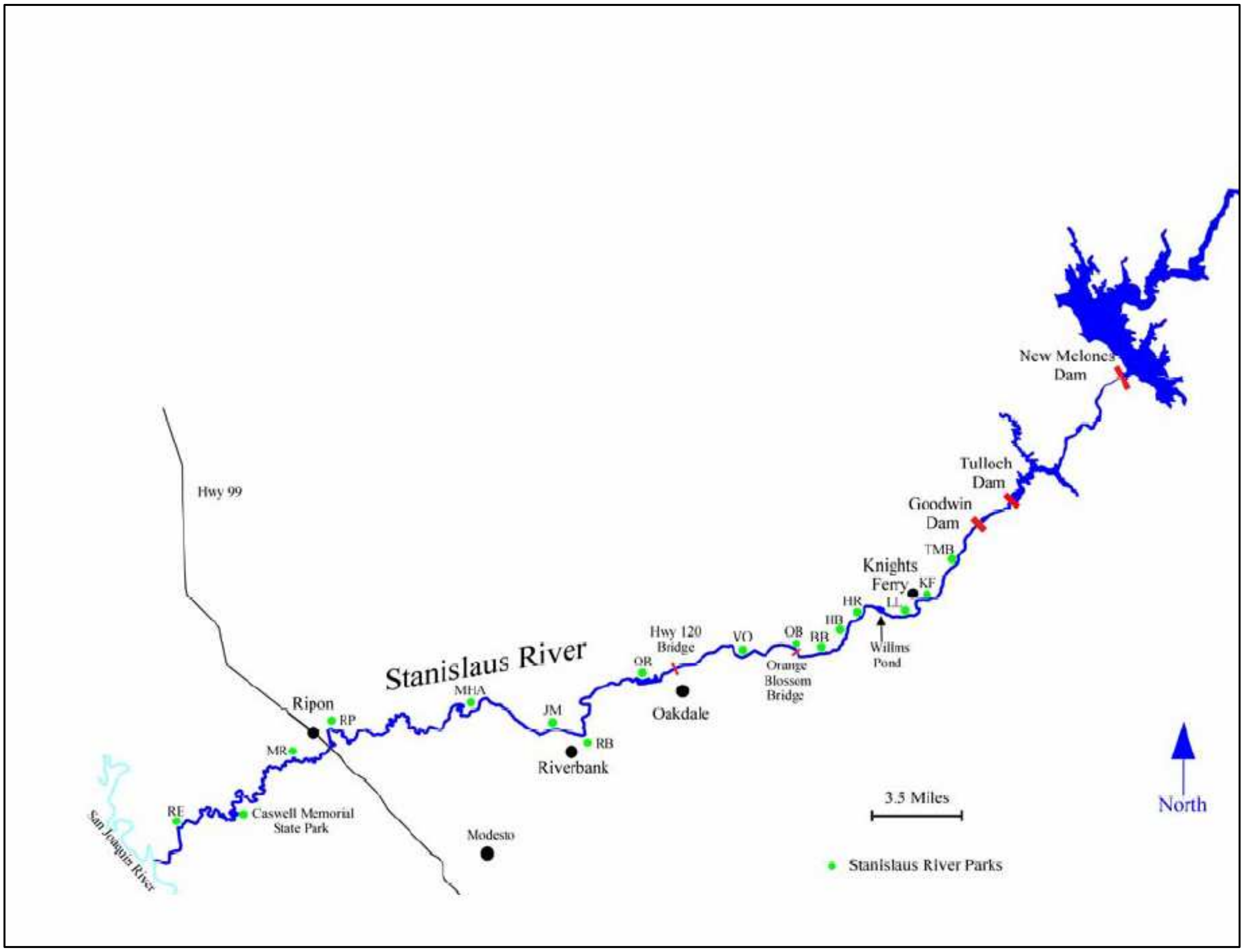

Figure 1. Map of LSR sampling locations. (Source: SRFG 2003).

Sampling Reaches: Each reach will encompass approximately one-half mile of river and all its aquatic habitat area. Reach boundaries where possible will be defined based on longitudinal and lateral gradients, channel confinement, stream habitat conditions, and riparian land use. The five chosen reaches are known to exhibit a wide range of habitat conditions that are representative of the LSR. Reach boundaries will be marked by survey tape.

Sampling Units: Sampling units will consist of 2-D polygons or cells mapped from the available habitat within each ½ mile sampling reach at the beginning of each survey period (see Subtask 3.2). Units will be classified into types by reach based on the physical characteristics as measured in the habitat surveys (Subtask 3.2). Each reach will contain a unique set of cells and cell habitat types. The general approach to habitat inventory surveys is classification of habitats into pool, riffle, run, glide, and backwater or off-channel habitats. While our classified types may fit readily into these categories, the more likely scheme will be sampling units representing subunits of these categories and then grouping the subunits into types based on specific habitat conditions that will include depth, velocity, substrate, bank slope, and shade/cover types. Other methodologies will be considered in defining habitat classification types (Kondolf et al. 2003).

Sampling Design: Sampling will be conducted during two two-week periods: one in February and one in May. These are approximate dates that are likely to encompass two distinct flows and a range of juvenile salmon and steelhead life history stages. Sampling will be stratified by period, reach, and habitat type. During each period, samples (snorkel survey observations) will be collected at random from among the various types by reach. From recent years flow gage data there appears to be several flow regimes: a base flow at approximately 250 cfs that occurs consistently in late October and winter-spring of drier years, another at 500 cfs, and one in the range of 750-1250 cfs in the spring (Figure 2).

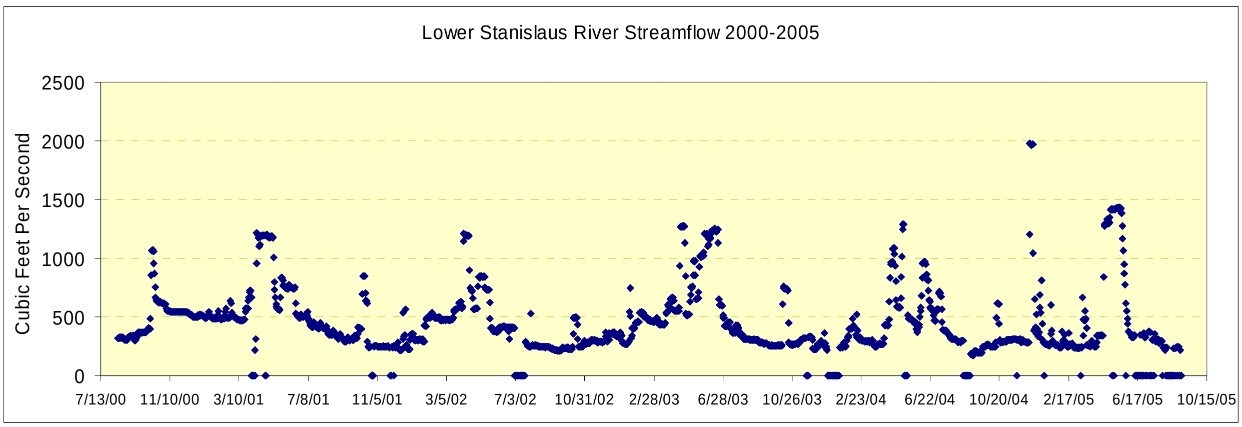

Figure 2. LSR daily-average streamflow 2000-2005 (Orange Blossom gage).

Sampled Variables: Variables measured in sampling units (sampled cells) will include numbers of fish observed by species and size range. Size ranges for salmonids will be as follows: 30-50 mm (fry); 50-70 mm (fingerlings); 70-90 mm (presmolts); 90-120 mm (smolts); 120-200 mm (advanced smolts); and 100-mm groups thereafter. Size ranges for non-salmonids will be <25 mm; 25-50 mm; and 50-mm groups thereafter.

Sampling Bias: Sampling efficiency will be estimated in several ways. First, observation efficiency will be measured by a second observer taking measurements on 5 percent of the samples in each survey period. Second, snorkeling and electrofishing surveys will be conducted at one of two lower survey reaches during each of the sampling periods.

Sample Variance (sampling error): Sample variances will be estimated from sample distributions for each survey period by reach by habitat type.

Database: Sampling survey data will be transferred from field data sheets to Excel/Access file database. Field data sheets will be scanned and pdf files catalogued and maintained for each data sheet. Databases will be compiled and submitted by survey period.

Data Analysis and Presentation: Sampling survey data will be represented for each survey by reach on GIS rectified aerial photos delineated for sample location via GPS locations recorded in survey sampling. Data will be presented by density per unit area of species and size groups within species. Data will also be statistically analyzed by Analysis of Variance, Regression, and Multivariate Analysis to test for differences among regions, periods, and habitat types. Species densities will be used as dependent variables and habitat conditions as independent variables.

Physical Habitat Surveys

FFC and INSE will conduct physical habitat surveys as follows:

Survey Method: The survey methodologies will include ground surveys and aerial photo and USGS map interpretation to define habitat sampling units (cells) and to characterize cells by measuring physical habitat attributes (variables) of the five reaches. Ground surveys will be conducted on foot and by kayak or swimming (snorkeling) during each survey period. Field mapping of substrate, vegetation, or features such as large woody debris will be accomplished through a combination of photo interpretation and field–based mapping using the image to draw polygons directly, or by mapping features with GPS equipment. Since the images are orthorectified, any digitized polygons can be overlaid using GIS on the original image. GIS can then be used to assign spatially–variable attributes of substrate, vegetation (cover) and roughness to each cell. The 2-D boundaries of each cell will be determined for each flow regime encountered in the surveys by marking boundaries on aerial photos with boundaries based on visible habitat characteristics.

In addition at one of the reaches, subsurface channel topographies will be derived at each flow regime using hydroacoustic–based mapping with a boat mounted real–time kinematic differentially–corrected survey grade Global Positioning System (GPS) integrated with a scientific–grade acoustic bottom profiling system. In addition, an acoustic doppler current profiling system (ADP) for measurement of the 3–dimensional velocity vectors throughout the water column will be integrated into the instrument package. Hydroacoustic mapping will be conducted at a discharge that is greater than the discharge at which the aerial photogrammetry is collected to ensure an overlap between the DTMs generated from these different data sets, and to minimize the potential for missing topographies where the acoustic mapping is limited by water depths at the stream margins. The location of each cell will be documented with GPS for the flow regime. The cells will be digitized onto GIS-rectified aerial photos using the GPS and field marked aerial photos.

Survey Design: Surveys will be conducted at the beginning of each fish survey period (February and May). These are approximate dates that are likely to encompass at least two flow regimes, as well as a range of juvenile salmon and steelhead life history stages. Survey data will be stratified by period, reach, and habitat type. A major difference from the fish survey is that during each period, survey data will be collected from all cells in each survey reach rather than a sample from each habitat type.

Survey Variables: Measurements of physical variables of the habitat within cells will include average depth, water velocity, lateral and longitudinal channel slope, water temperature, turbidity, substrate, and cover type (riparian SRA, instream woody or rock material, aquatic vegetation). Each of these variable categories would have one or more parameters to represent the variable. For example, cover type would involve instream and overhead cover, with riparian cover represented by the amount of overhang, shade, density, depth, distance to shoreline, and height of the riparian SRA vegetation.

Sampling Bias: Sampling efficiency will be estimated in several ways. First, observation efficiency will be measured by a second observer taking measurements on 5 percent of the samples in each survey period. Second, snorkeling and electrofishing surveys will be conducted at one of two lower survey reaches during each of the sampling periods, thus providing a second measurement of physical habitat conditions. Third, lower reach surveys will be compared directly to screw trap survey physical data for common sampling units.

Sample Variance (sampling error): Statistical variances will be calculated from survey data for each survey period by reach by habitat type.

Database: Survey data will be transferred from field data sheets to Excel/Access file database. Survey data will be represented for each survey by reach on GIS rectified aerial photos delineated for sample location via GPS locations recorded in surveys. Field data sheets will be scanned and pdf files catalogued and maintained for each data sheet. GPS locations will be recorded in a GPS data dictionary for each survey period. Databases will be compiled and submitted by survey period. GPS coordinates and polygons drawn on aerial photos will be digitized by CAD technicians and then electronic Shape files submitted to GIS team to develop ArcMap GIS database. ArcMap GIS databases will combine the CAD derived Shape files and Excel/Access database files into one common database.

Data Analysis and Presentation: The Excel/Access and ArcMap databases will be used to analyze and present information. Data will be presented by parameter for each cell in the survey area using ArcMap routines. Data will also be statistically analyzed using Analysis of Variance, Regression, and Multivariate Analysis to test for differences among reaches, periods, and habitat types. Differences and relationships among parameters will be analyzed using the same statistical techniques.

Data Analysis and Reporting

The databases developed will be translated into geo-referenced ArcMap GIS files for data analysis and reporting purposes. Three databases will be translated: (1) the drawn polygons will be digitized onto aerial rectified photo files located by GPS points; (2) the fish density by species and size-group data will be incorporated by polygon cells in the

ArcMap database; and (3) the physical data collected in field surveys and photo/map interpretations will be incorporated by polygon cell.

Habitat Use Maps

A geo-referenced database will be developed in ArcMap GIS for each of the five survey reaches of the LSR. Databases will be developed for each flow regime surveyed (two for fish and physical habitat). The database individual cell units will be populated with snorkel survey observation data (density by species and size range) and physical habitat survey data from field surveys and map/aerial photo interpretation. Each cell defined for each survey reach will be populated by the corresponding fish or physical data (including physical survey and photo/map interpretative data) will be input for each cell. For snorkel survey data, only cells sampled will be included by cell type. The unsampled cells will be populated by the statistical average and variance for the type by survey by reach.

Once the ArcMap database is complete for each survey period, fish density and physical habitat conditions will be displayed by cell for each survey reach. Each survey will have a discrete set of cells with each cell having unique (or sample average) fish or physical habitat data, which can be displayed via an array of color codes and cell patterns.

Fish density will be displayed in tabular form by survey by reach by cell type with statistical confidence intervals (CI). CIs for fish densities will be determined from sampling among the cells of a type (by survey and reach), whereas physical data CIs will be calculated from the observations of the total population of cells by type by reach by survey. Sampling error from the small subset of observations where accuracy and bias were estimated will be incorporated into the error estimates of the total population by reach by survey period (and flow regime). Total and mean estimates of abundance by size groups will have calculated CIs based upon survey variance and sampling error by reach and survey. For each survey and reach, color coded density/abundance displays with density coded by color types presented in each cell (sampling unit).

Data Analysis

Data analysis will occur in both the empirical statistical and habitat model technical approaches as follows.

Empirical Approach

The databases, associated statistical output, and graphical and tabular displays will be used to describe variability in habitat use, availability, and quality within survey reach, among reaches, and within and among survey periods (and flow regimes). In addition, statistical tests will be performed to test the following questions (hypotheses):

1. Are there differences in the amount of specific habitat types among surveys (flow regimes)? *(Note that direct comparison among flow regimes for fish density may not be possible because different species and life stages are likely to occur during the two survey periods. However, the two surveys should provide a clear picture as to what habitat types hold higher densities of specific species and life stages.)*

2. Are there differences in fish densities among habitat types between and among survey reaches? For example, Reimers (1971) found salmon fry disperse downstream of spawning areas, therefore we may be able to determine spawning areas from the fry distributions. Distances from know spawning areas may also be another variable to include in the analyses of distribution patterns.
3. Are there habitat differences that can be used to predict differences in fish use of habitats within and among reaches.
4. Are there differences in the amount of high quality habitat types within and among reaches that could be related to flow regime (survey periods).
5. Are the degrees of significance or strength of relationship for any of the above relationships significant based on statistical analysis.

The data displays and statistical analyses will be used assess the following:

6. What flows are more optimal and to what degree for salmon and trout, respectively.
6. The degree to which fish use of habitat types varies and what habitat types appears to be preferred by all species and life stages.
6. What habitats appear to be limiting by species and life stage.
6. Whether habitat preferences varied by species and life stage within species with survey period (season).

Other analyses include the following:

- Relate fish use and habitat conditions to flow and river location.
- Relate fish density to the degree of spawning among reaches.
- Relate fish use and distribution among habitats to differences in habitat and total density of fish within and among reaches.

The key products of these analyses will be (1) statistical means and variances, and mean-square-errors from analysis of variance and regression by species and life stages for specific habitat types, and (2) the area of habitat for each habitat type under the two flow regimes. From these we will be able to predict the distribution and spatial extent of specific habitat types in the LSR.

Analytical tools to be employed included Analysis of Variance, Regression Analysis, and Multivariate Analysis. Statistical packages to be used include Microsoft Excel Analysis ToolPac, various commercial add-on packages available for MS Excel, and the ArcMap Extension called Geostatistical Analyst.

2D Modeling Approach

The 2D hydrodynamic and habitat modeling approach will be evaluated at one reach during the two surveys. Three dimensional channel topography, substrate, cover and vegetation polygon maps and hydrodynamics model calibration data (e.g., water surface elevations at the two flows) at one modeling sites approximately ½ mile in length where empirical fish habitat data has also been collected. The three dimensional channel topography is generated using a combination of low–elevation high–resolution aerial photography, hydroacoustic–based mapping of the subsurface channel topography (i.e., under water topography), auto-tracking total station surveying, laser based surveying and/or conventional surveying.

The calibrated 2D hydrodynamics model and polygons of substrate, cover, etc. are then used to generate habitat conditions (depth, velocity, substrate, cover, distance to cover, distance to waters edge, etc.) within the modeling site over a wide range of flows (e.g., 50 to 1,500 cfs). These results can then be extrapolated to the entire river based on the empirical habitat mapping data of the entire river. Habitat modeling, given the above physical data set, is flexible and can be tailored to the results of the empirical mapping observations. The exact same physical attributes that are determined to be important in the empirical data collection can be employed in the 2D habitat modeling. This is the intent of the proposed approach. However, if more traditional PHABSIM type analyses are also desired (standard suitability criteria methods), they can be provided from these data.

The cell size within the 2D modeling sites will be as small as 0.5-1.0 m. These cells can be aggregated into any larger size appropriate to represent meso-scale habitat features determined important to species and life-stages from the statistical analyses. If appropriate behavioural-based habitat rules developed from the statistical analysis (or elsewhere) can be incorporated into the modeling.

Initial Study Report

Data displays and results of analyses will be presented in an Initial Study Report. The report will follow standard scientific paper format. The report will include a complete description of study purpose and objectives, methods employed, results, discussion (relating to available literature), and literature cited. The discussion will include relevance of study results to management questions on the LSR, specifically how differences in flow affect fish habitat use and abundance patterns by season and reach, and what flow changes would facilitate potential improvements in fish populations in the LSR.

The report will focus on the applicability of the applied methods in determining the effects of instream flow on fish production and habitat use patterns in the LSR. The standard Instream Flow Incremental Methodology (IFIM) would develop habitat suitability relationships by species and life stage for univariate habitat parameters, and then relate to predicted weighted suitable areas calculated for the river based on an array of sampled cross-sections to provide a relationship between the instream flow rate and the amount of available suitable habitat for each species and life stage. Predictions are based on hydraulic modeling incorporated into the IFIM tool packages.

The proposed methodology can provide the same information provided in the standard IFIM approach, but the proposed methodology greatly enhances the standard methodology by using statistical survey methods where survey sampling provides estimates with confidence limits of the densities and total numbers by species and size groups by habitat type, reach, and flow regime. While the IFIM method can extrapolate between measured flow regimes using hydraulic models, the proposed method can establish the fish habitat-flow relationship statistically and hydraulically by measuring fish habitat-flow relationship at distinct flows and extrapolating and interpolating the results using hydraulic modeling. The RFP stipulates the empirical habitat surveys should be done at two flows. Strict empirical habitat mapping would likely provide satisfactory habitat versus flow relationships if many flows were mapped. However, if only two flows were mapped there would only be two points on a graph showing the relationship between fish and flows. The approach we have proposed provides a method to interpolate and extrapolated to a wide range of flows if the following can be developed: (1) sufficient numbers of flow regimes can be mapped for habitat types to develop a reasonable statistical relationship between flow rate and the amount of specific habitat types; and (2) a 2D hydrodynamics model can be developed that simulates the distribution and amounts of habitat types at flows that were not empirically mapped.

Summary of Technical Approach

The proposal incorporates two technical approaches that will be integrated to meet the objectives of mapping fish habitat under different flows in the LSR. The expanded 2D-IFIM approach with 2D hydrodynamic and habitat modeling and the empirical sampling approach of fish and physical parameters will provide two direct approaches toward the project objective. From that mapping we will be able to develop statistical relationships for fish species and life stages with habitat types. We will be able to relate fish habitat value to flow empirically for the measured flows, however, we have the 2D modeling approach to provide that estimate at the measured flows as well as unmeasured flows. This is a double-pronged approach to the key technical challenge of the study.

Perhaps most important is FFC five years experience snorkeling the river from Goodwin Dam downstream, which provides the knowledge and ability to accomplish the extensive amount of data collection. In addition to the Stanislaus River, the FFC has conducted similar habitat and fish surveys in the lower American River over the past three years. At the FFC, Tom Cannon and Trevor Kennedy have collaborated on fish habitat studies on many Central Valley rivers and the Delta. As a biostatistician, Tom Cannon brings the expertise to perform the empirical statistical approach that he has employed in the past several years on the lower American, Cosumnes, Calaveras, and Stanislaus River fish habitat studies for the FFC.

The CAD/GIS mapping and database aspects of the study will be handled by Wildlands habitat mapping team who have worked with the FFC for the past five years mapping fish habitat in the Delta. Wildlands team is especially adept in mapping large habitat landscape with all of the state of the art CAD and GIS mapping, database, and analytical tools.

Craig Addly’s team brings the state-of-the-art technology of habitat modeling that he has employed on the Klamath and Trinity River and has begun on the Calaveras River working with the FFC. The INSE team will collect the key hydraulic data to characterize the complex physical habitat of the LSR using hydrodynamics modeling and allow habitat modeling over a range of targeted flows.